XMASS

ICRR, University of Tokyo
K. Kobayashi

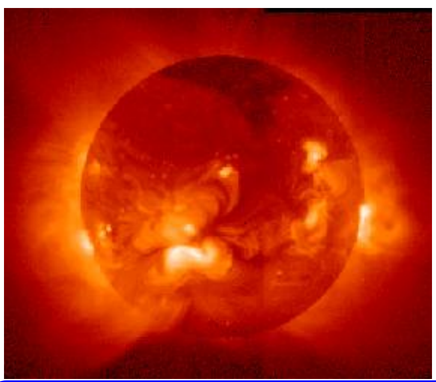
Jan. 31st, 2013
“Closing in on dark matter”, Aspen, USA

XMASS experiment

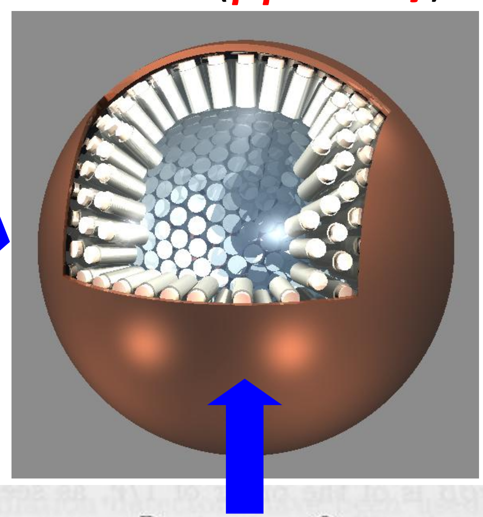
- **What is XMASS?**

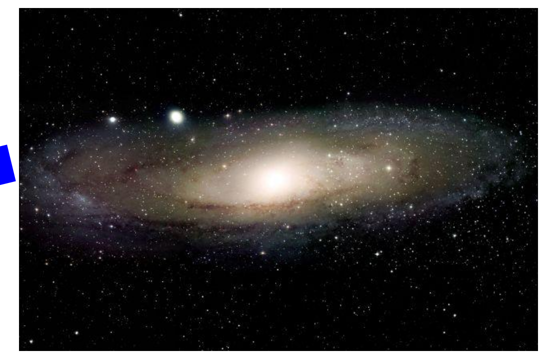
  Multi purpose low-background and low-energy threshold experiment with liquid Xenon

- **X**enon detector for Weakly Interacting **MASS**ive Particles (**DM search**)
- **X**enon **MASS**ive detector for solar neutrino (**pp/^{7}Be**)
- **X**enon neutrino **MASS** detector (**$\beta\beta$ decay**)

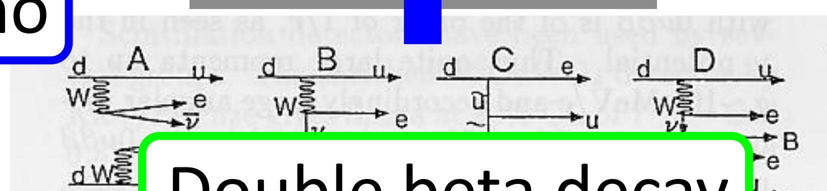


Solar neutrino





Dark Matter



Double beta decay

+axion, etc

XMASS collaboration

ICRR, University of Tokyo	K. Abe, K. Hieda, K. Hiraide, Y. Kishimoto, K. Kobayashi, S. Moriyama, K. Nakagawa, M. Nakahata, N. Oka, H. Ogawa, H. Sekiya, A. Shinozaki, Y. Suzuki, O. Takachio, A. Takeda, D. Umemoto, M. Yamashita, B. Yang
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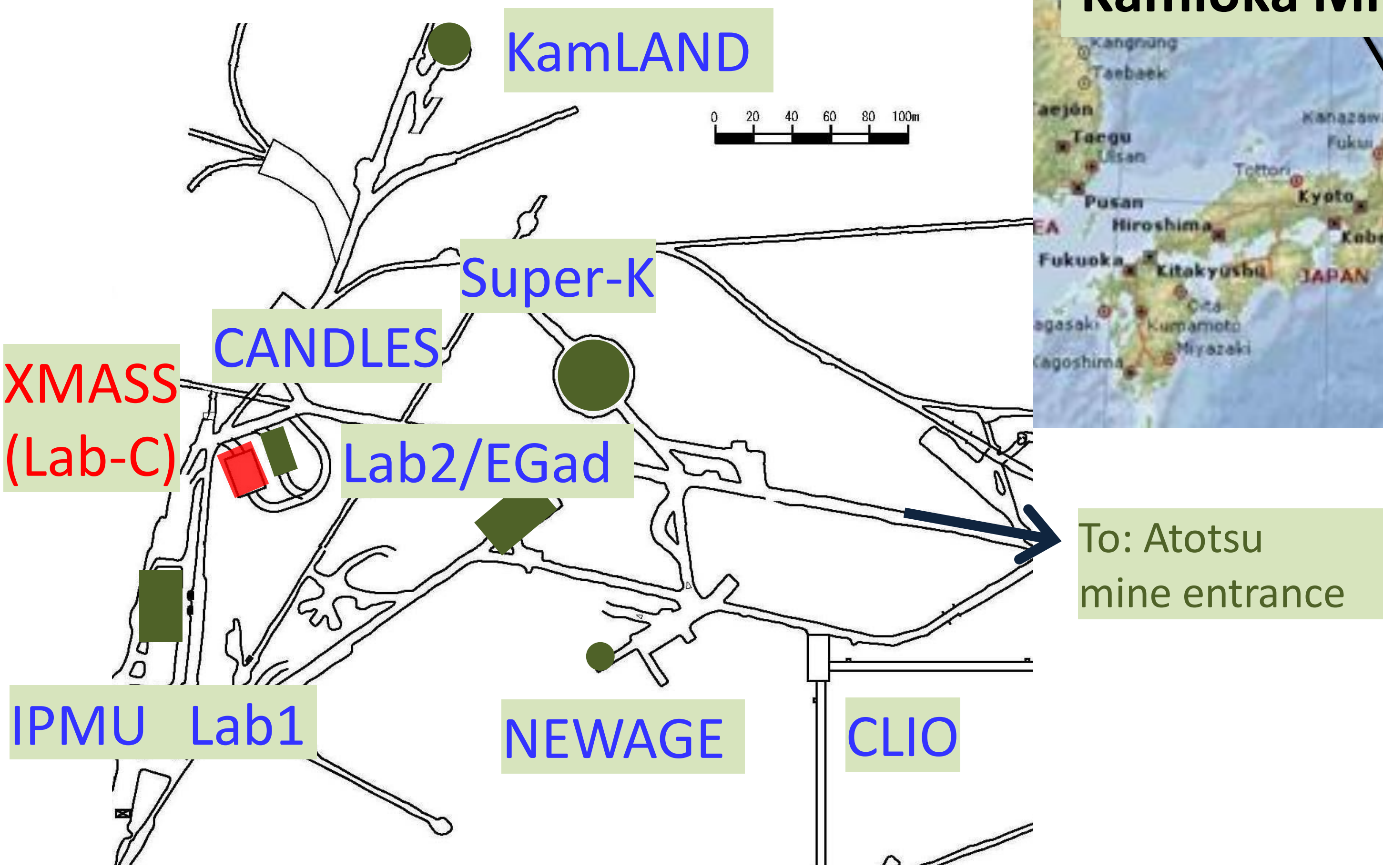
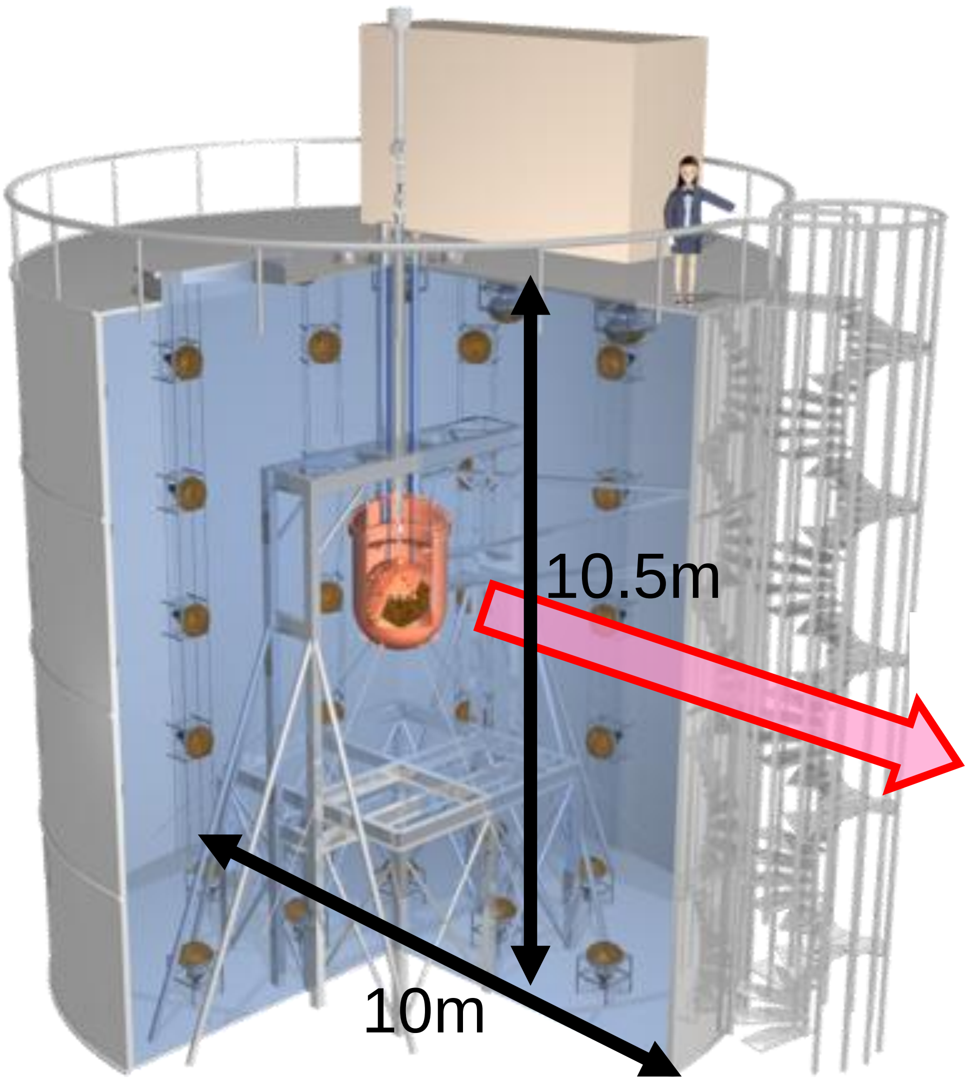
Tokai University	F. Kusaba, K. Nishijima
Gifu University	S. Tasaka
Yokohama National University	K. Fujii, I. Murayama, S. Nakamura
Miyagi University of Education	Y. Fukuda
STEL, Nagoya University	Y. Itow, K. Masuda, H. Takiya, H. Uchida
Sejong University	N.Y. Kim, Y. D. Kim
KRISS	Y. H. Kim, M. K. Lee, K. B. Lee, J. S. Lee

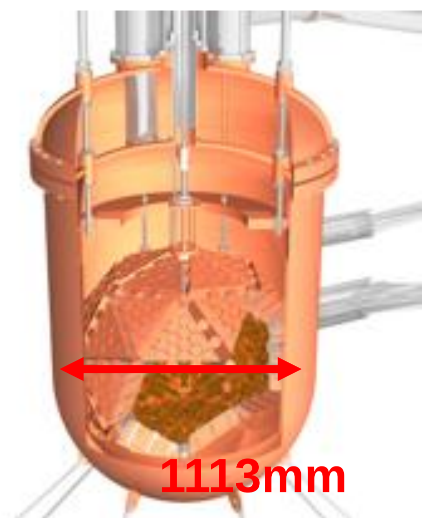
Kamioka mine



detector



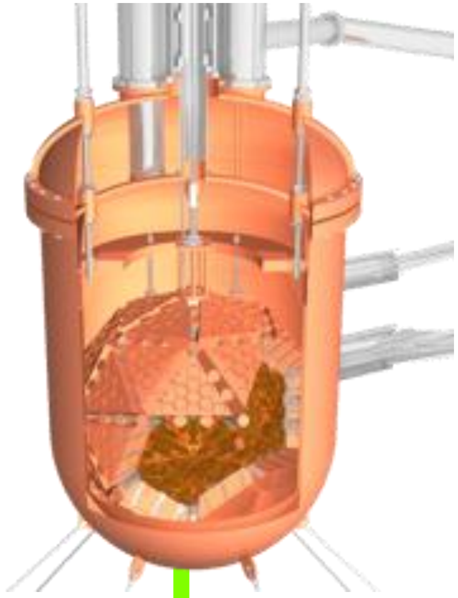
•72 20-inch PMTs will be installed to veto cosmic-ray muon ($<10^{-6}$ for thr-mu, 10^{-4} for stop-mu).
•Water is active shield for muon induced neutron and also passive shield for gamma-ray and neutron from rock/wall.
•IVC and OVC are made of OFHC (Oxygen-free high thermal conductivity) copper

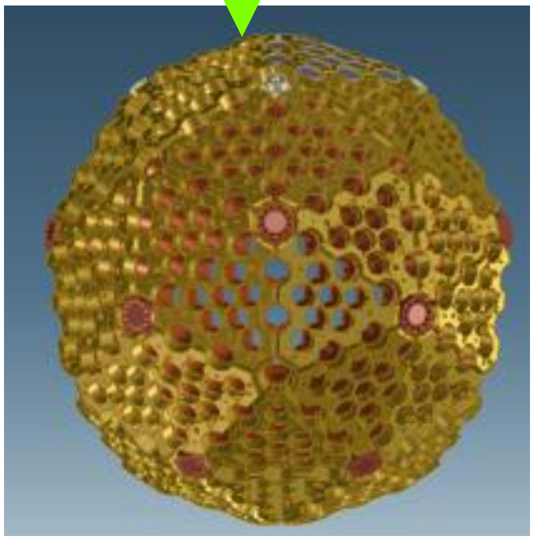


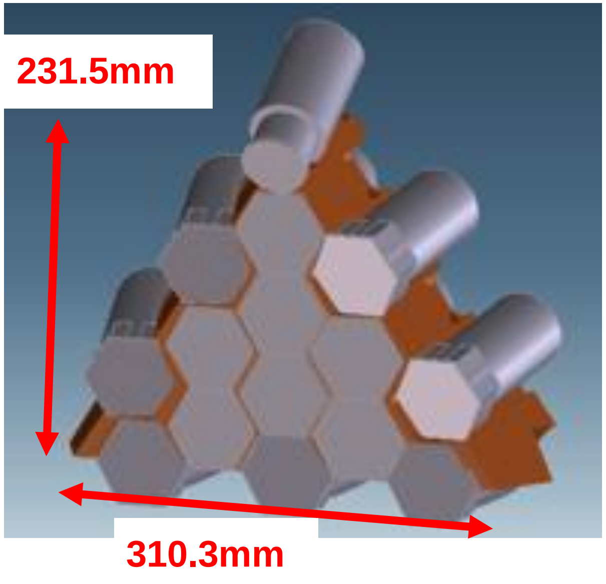
OVC

IVC

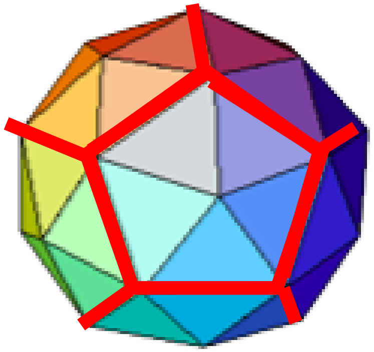
Detector design detail







pentakisdodecahedron



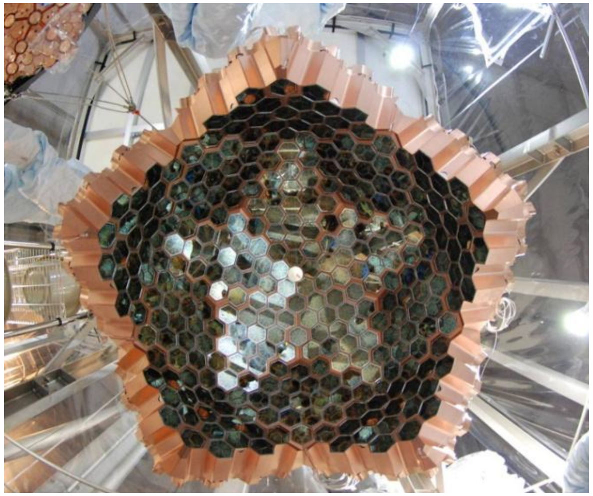
Hexagonal PMT
Hamamatsu R10789

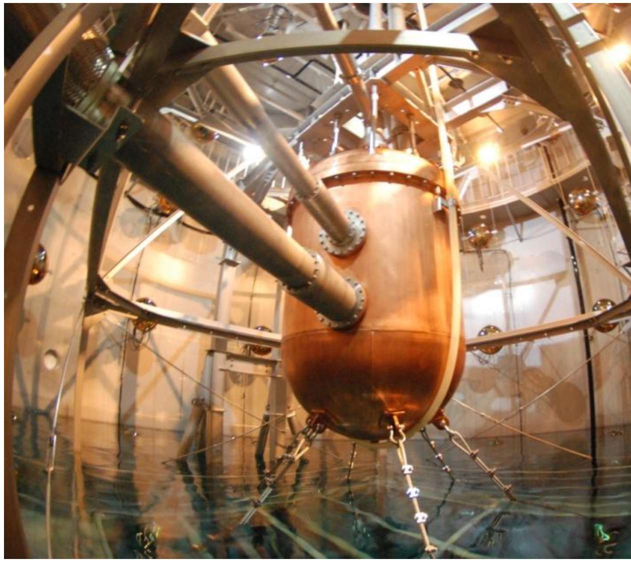
- 60 triangles
- Total: 642PMTs
- Photo coverage: 62%
- Diameter: ~800mm

XMASS detector,
K. Abe et al, arXiv:1301.2815

Detector Construction

September 2010:
Construction Completed





Calibration system

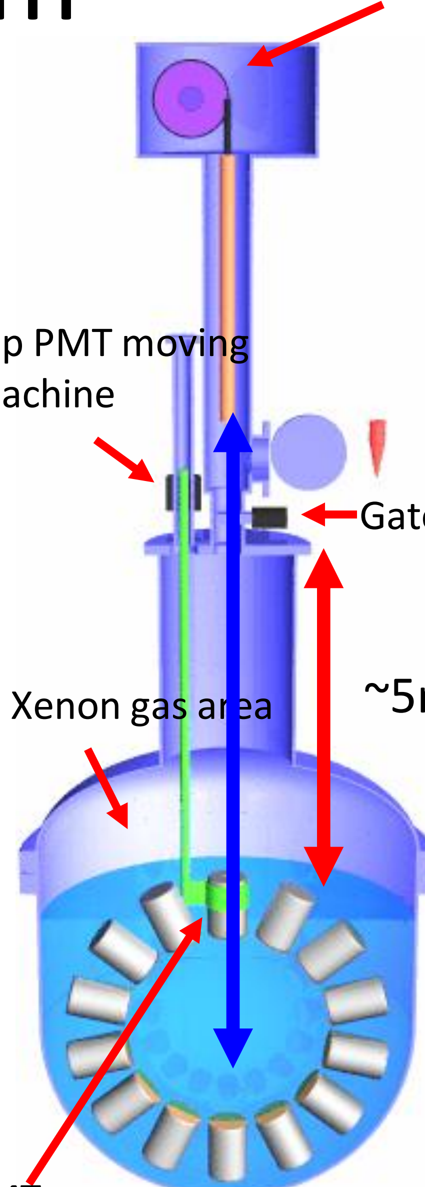
RI sources

	energy [keV]	RI	φ [mm]	package
(1) Fe-55	5.9	350	5	brass
(2) Cd-109	22, 25, 88	800	5	brass
(3) Am-241	59.5	485	0.15	SUS
(4) Co-57	122	100	0.21	SUS

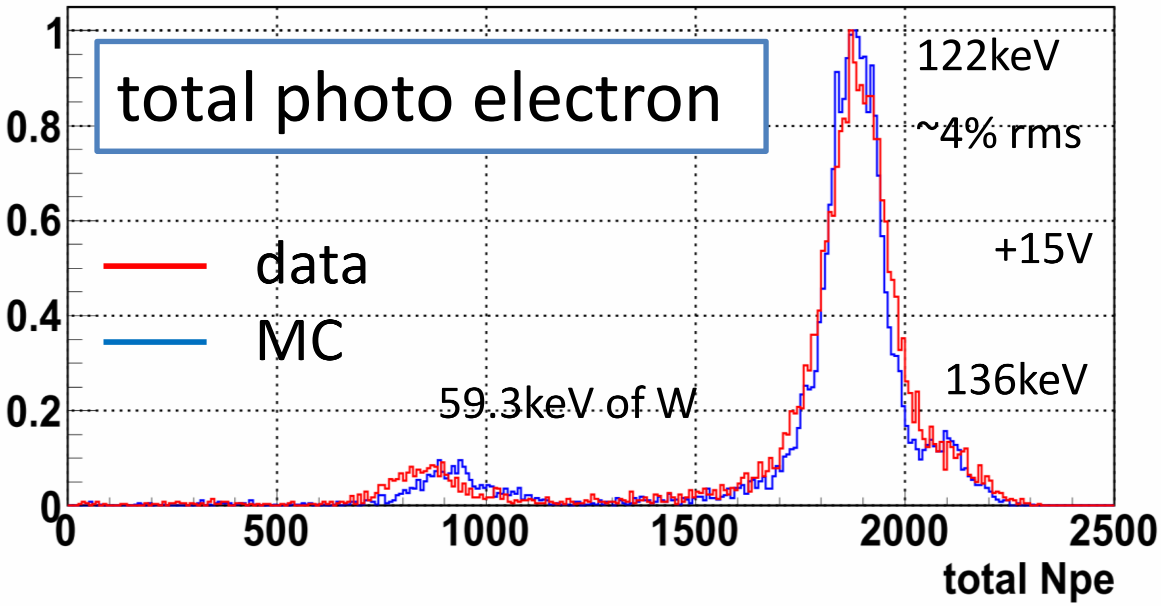
RI source with holder

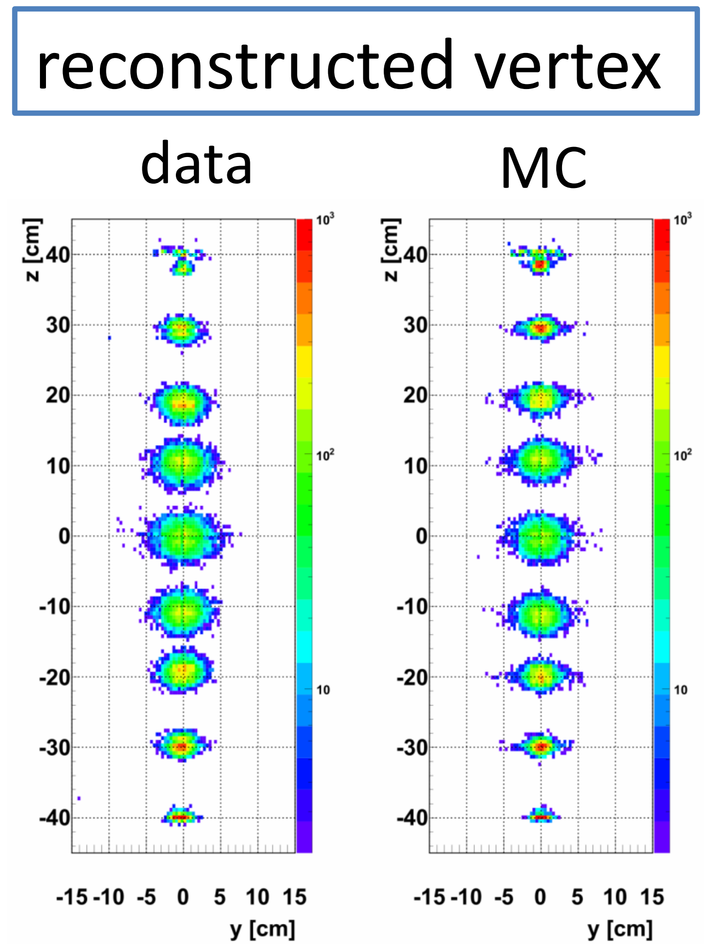
adaptor(SUS304)

OFHC



Detector response for a point-like source (~WIMPs)

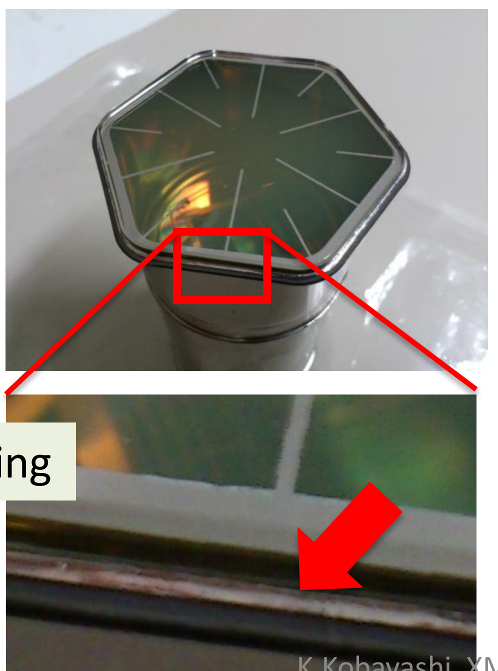




- ^{57}Co source @ center gives a typical response of the detector.
- 14.7p.e./keV_{ee} (⇔ 2.2 for S1 in XENON100)
- The pe dist. well as vertex dist. were reproduced by a simulation well.
- Signals would be <150p.e. exp shape.

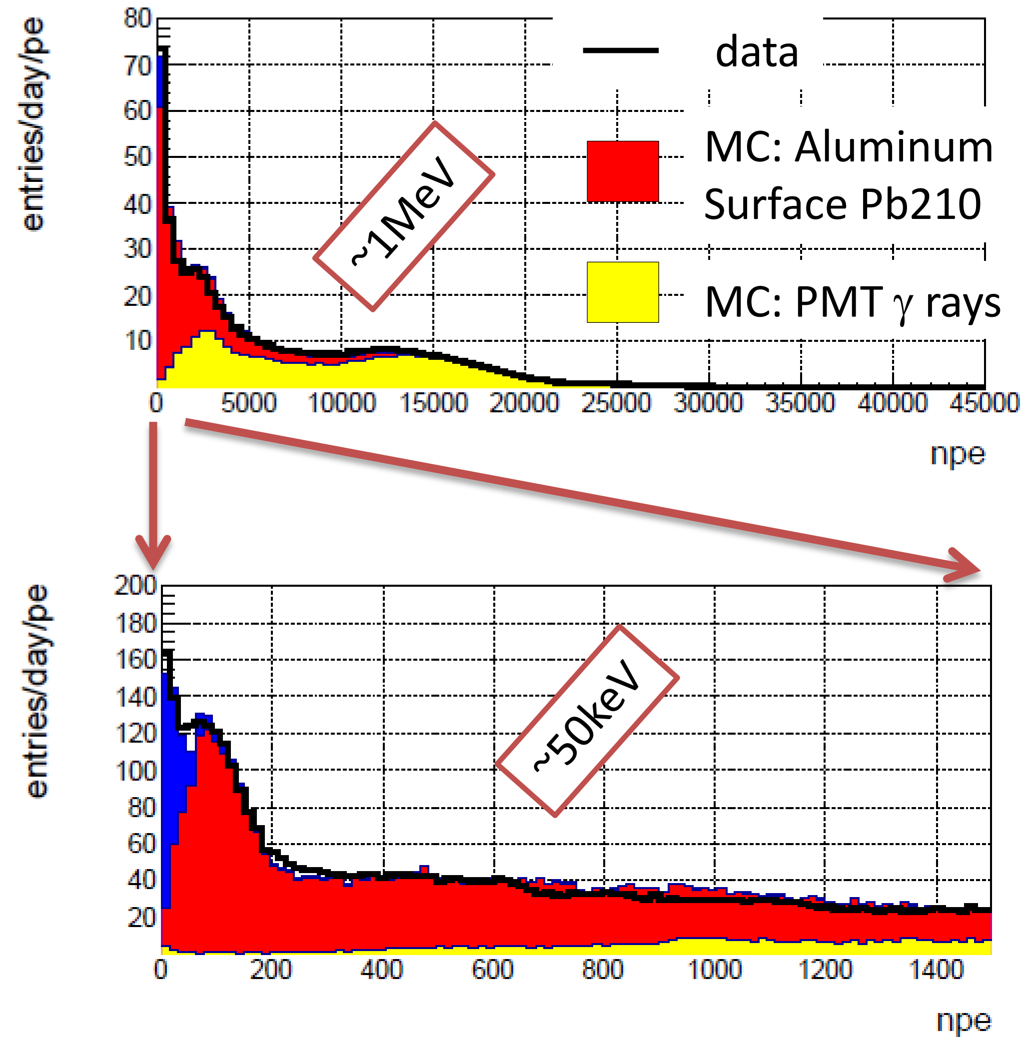
Background and its understanding

- Major origin of BG was considered to be γ from PMTs. But the observed data seemed to have additional surface BG.
- Detector parts which touch liquid xenon were carefully evaluated again:
  - Aluminum sealing parts for the PMT (btw metal body and quartz glass) contains U238 and Pb210 (secular equiv. broken).
  - GORE-TEX between PMT and holder contains modern carbon (C14) 0~6+/-3%.



background contribution to NPE spectrum

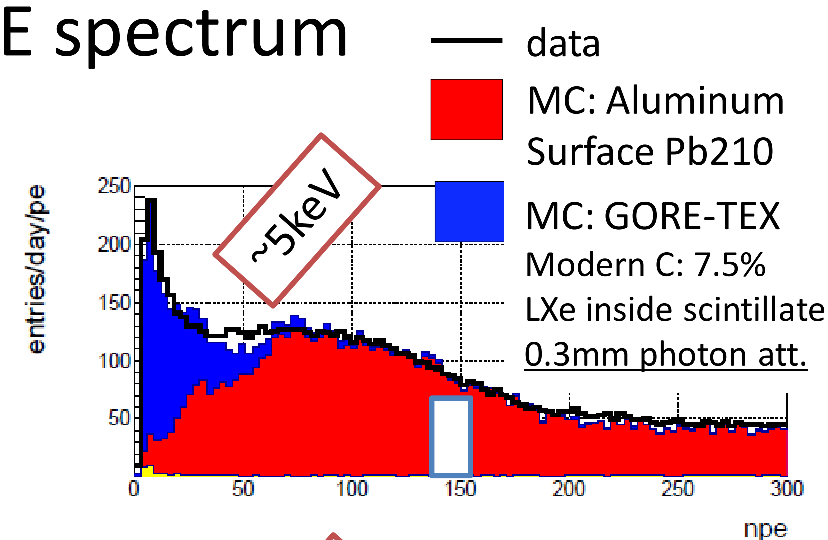
- Three contributions to the NPE spectrum
  1. High energy (0.1-3MeV): PMT γ rays: <u>Measured by Ge detectors and well understood.</u>
  2. Mid. energy (5keV-1MeV): Aluminum and radon daughters: <u>Measured by Ge det. and consistent with observed α-ray events</u> (61/64mcps in data/MC). Rn daughters on the inner wall identified by α events.

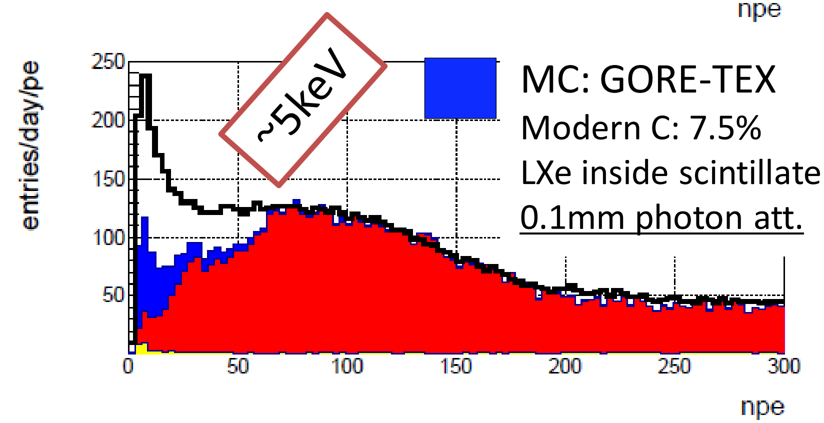


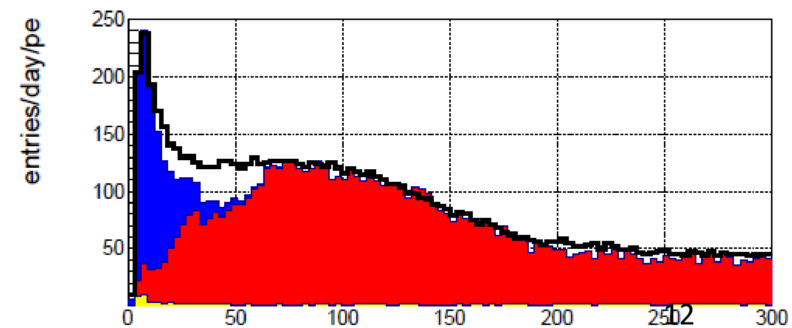
background contribution to NPE spectrum

3. Low energy (0-5keV): Under study.

Prediction based on some assumptions on GORE-TEX gives a similar shape. But assumption dependent. Confirmation possible only by removing the GORE-TEX.



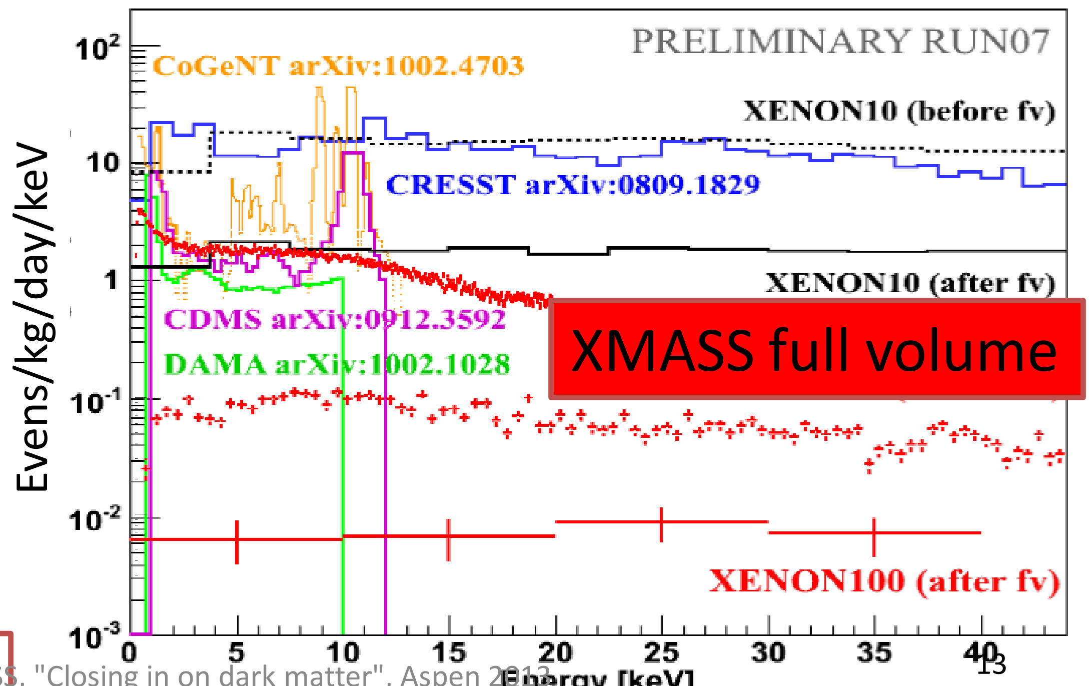




BG >5keV (the design energy thre.) is well understood!

Low background even with the surface BG

- <u>Our BG is still quite low, even with the extra surface BG!</u>
- In principle, the surface BG can be eliminated by vertex reconstruction. Optimization of the reconstruction program is on going to minimize a possible leakage to the inner volume.
- <u>Our sensitivity for the low mass WIMP signals at low energy without reconstruction will be shown.</u>



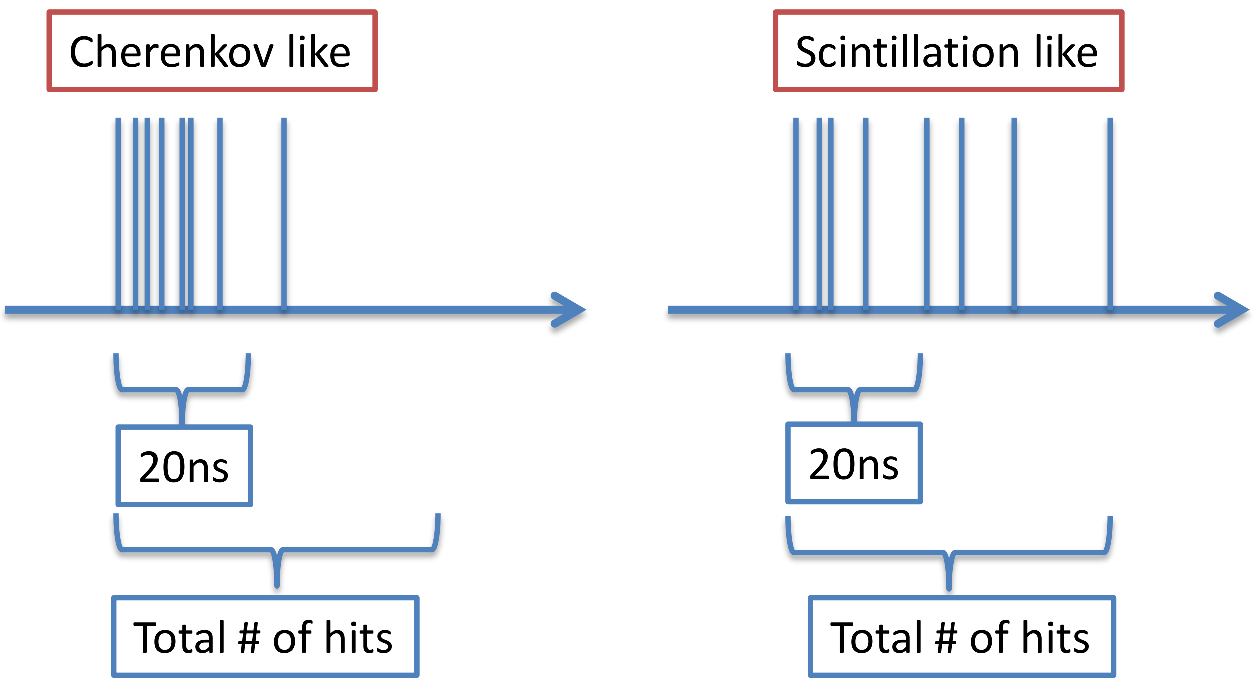
E. Aprile, 2010 Princeton

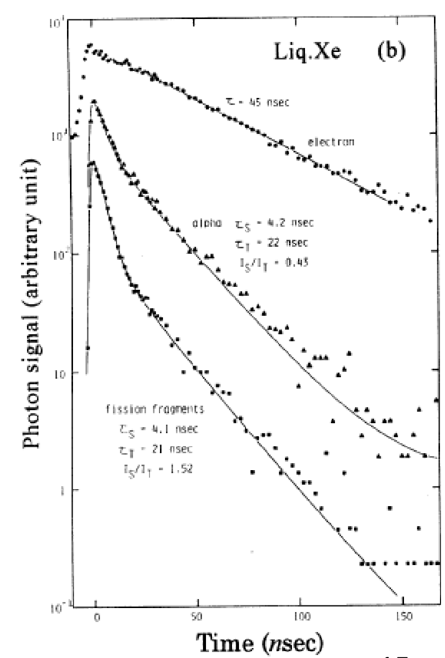
Low energy, full volume analysis for low mass WIMPs

- The dark matter signal rapidly increase toward low energy end. The large p.e. yield enables us to see light WIMPs. Try to set absolute maxima of the cross section (predicted spectrum must not exceed the observed spectrum).
- The largest BG at the low energy end is the Cherekov emission from ^{40}K in the photo cathodes.
- Selection criteria
  - Triggered by the inner detector only (no water tank trigger)
  - RMS of hit timing <100ns (rejection of after pulses of PMTs)
  - Cherenkov rejection
  - Time difference to the previous/next event >10ms

Detail of the Cherenkov rejection

- Basically, separation between scintillation lights and Cherenkov lights can done using timing profile.
- (# of hits in 20ns window) / (total # of hits) = "head total ratio" is a good parameter for the separation.

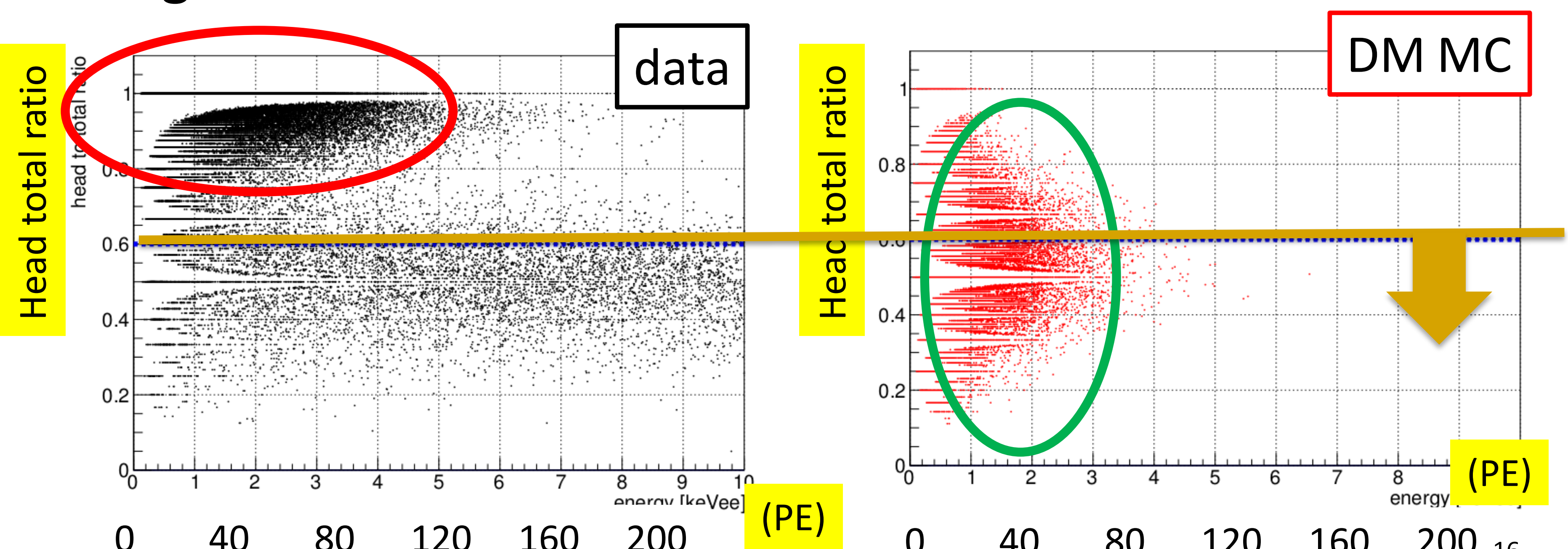




A. Hitachi et al., Phys. Rev. B 27 (1983) 5279.

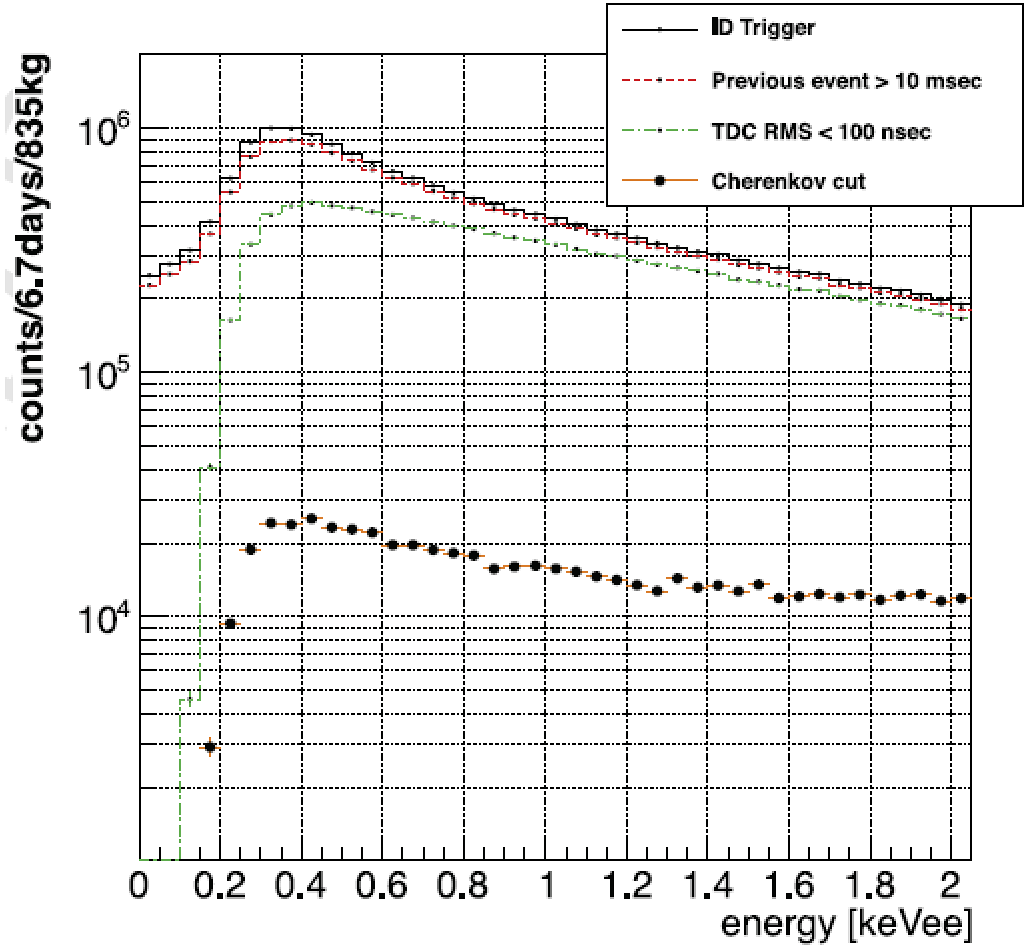
“head total ratio” distribution

- Cherenkov events peaks around 1 ⇔ scintillation ~ 0.5
- Low energy events observed in Fe55 calibration source as well as DM simulation (t=25ns) show similar distributions.
- Efficiency ranges from 40% to 70% depending on the p.e. range.



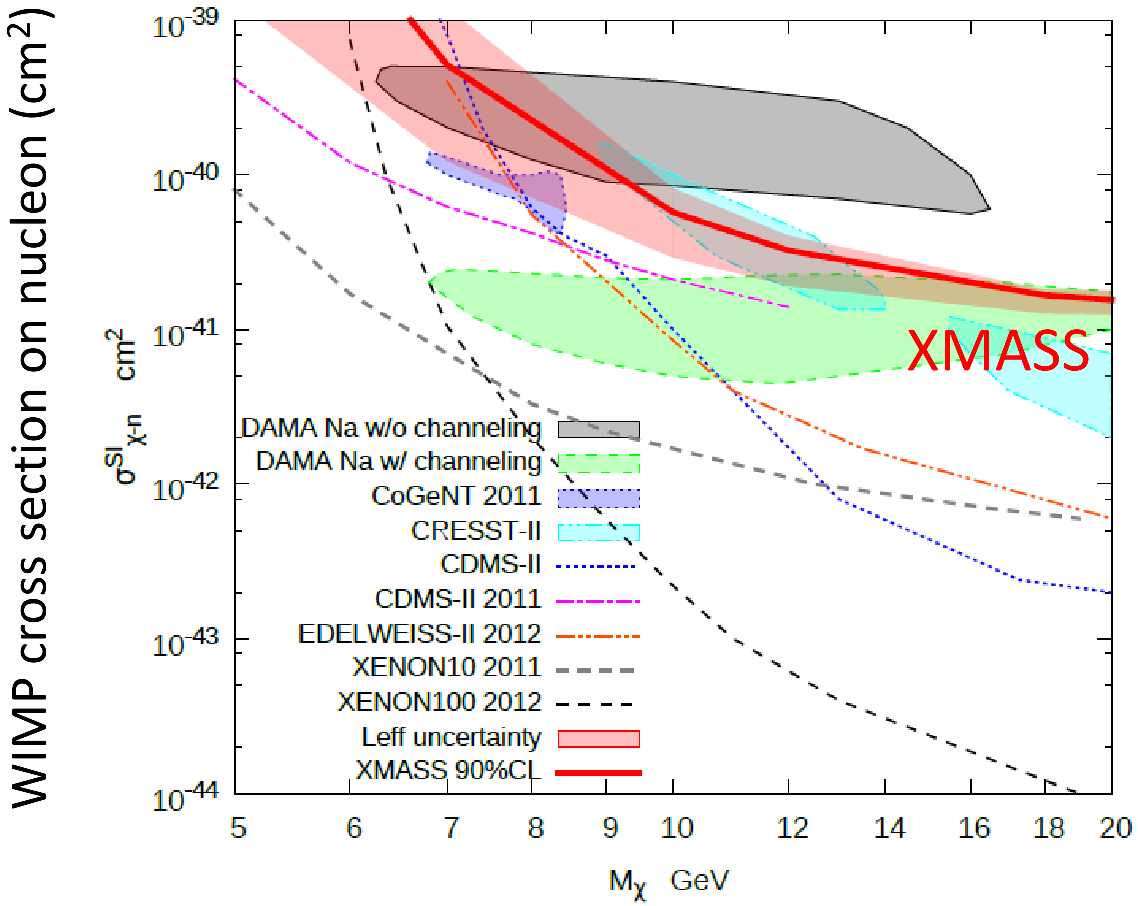
p.e. distribution after each cut

- 6.70 days data
- The Cherenkov events are efficiently reduced by the cut.



exclusion region

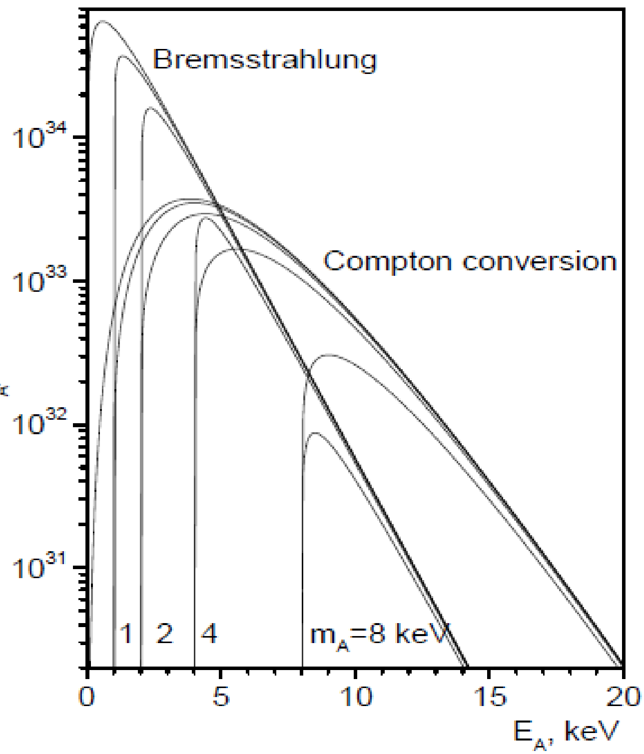
- Sensitive to the allowed region of DAMA/CoGeNT.
- Some part of the allowed regions can be excluded.



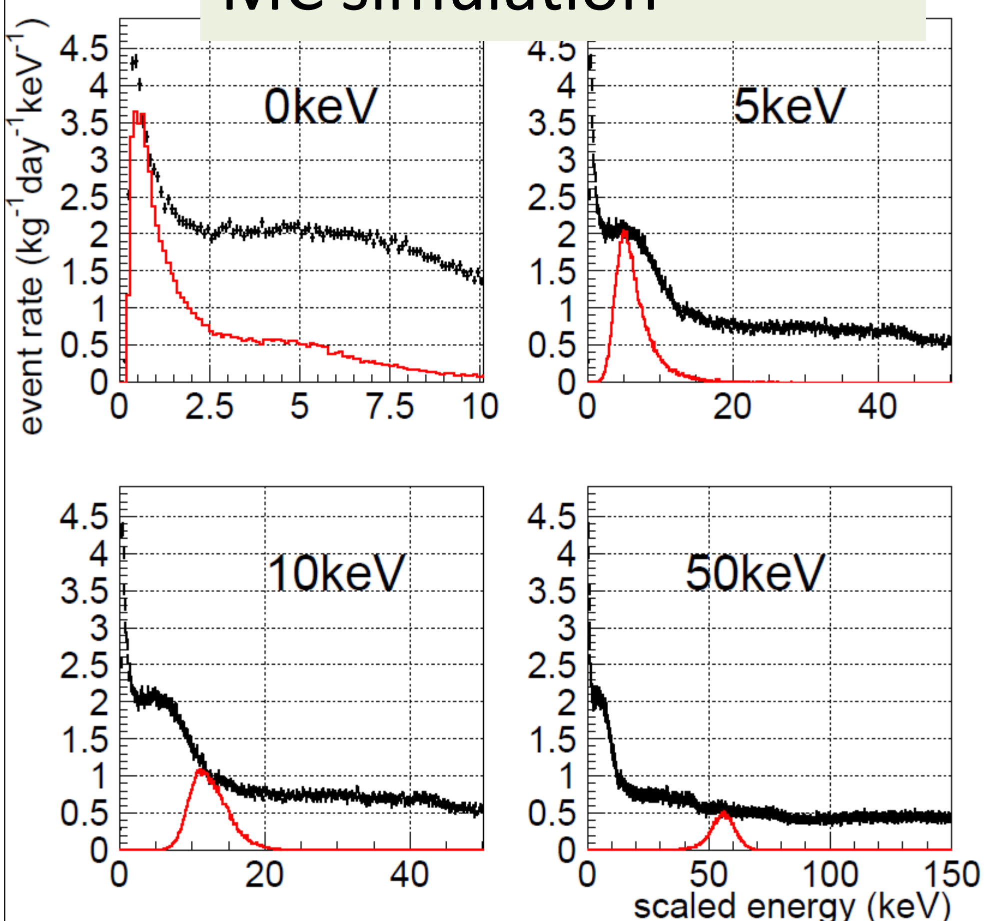
Light WIMP search in XMASS, K. Abe et al, Phys. Lett. B 719 (2013) 78-82, (arXiv:1211.5404)

Solar axion search
Bremsstrahlung + Compton: gaee only

- Large flux can be expected for DFSZ axions.
- m_A=0 by Derbin gaee=1
- Analytical expression for mA=0 is in PRD 83, 023505 (2011)



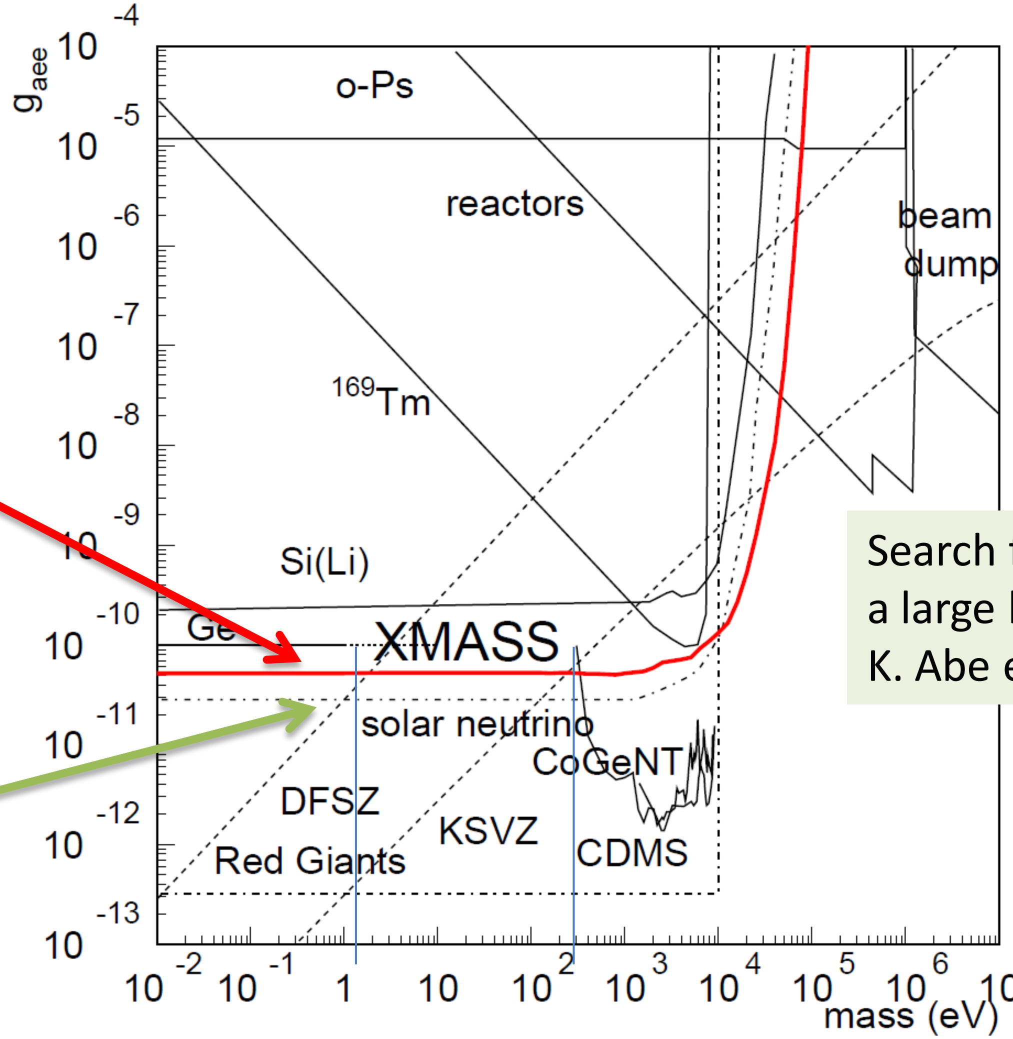
Expected signals and MC simulation



constraint on axion-electron coupling

XMASS Limit by solar axion 5.4e-11

Solar limit 2.8e-11

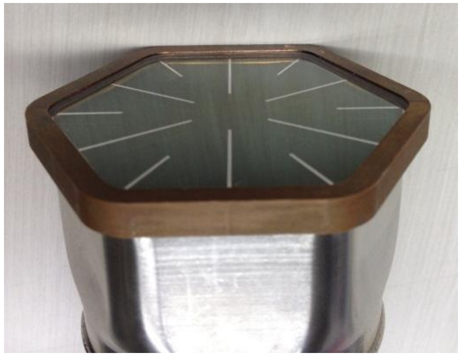


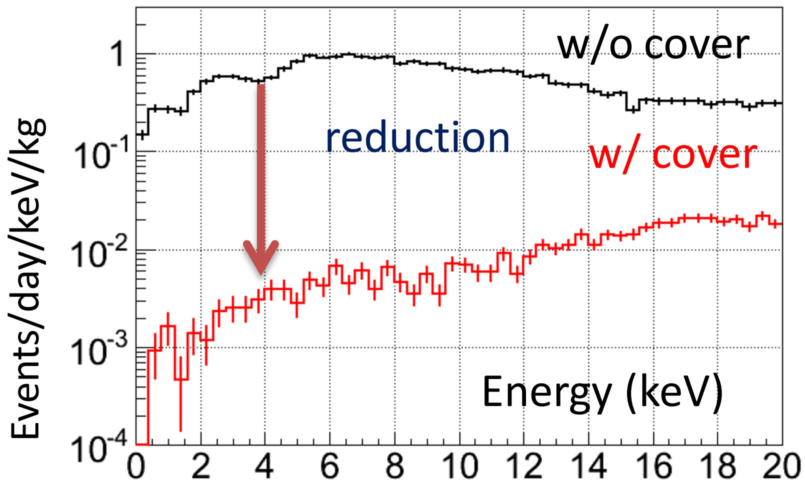
Search for solar axion in XMASS, a large liquid-xenon detector, K. Abe et al, arXiv:1212.6153

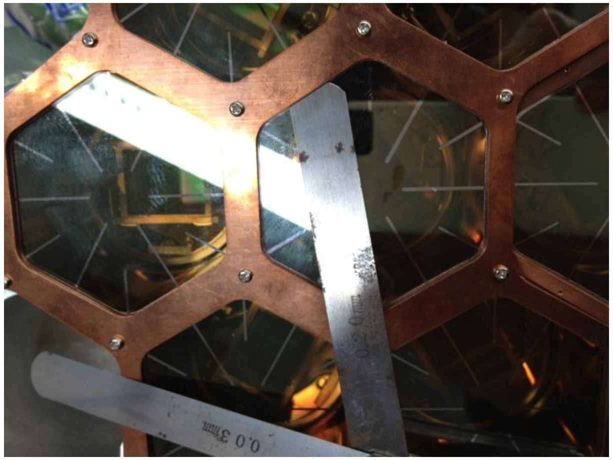
Allowed mass
< 250eV for KSVZ
<1.9eV for DFSZ

refurbishment work

- PMT Al is covered by copper.
- To simplify the structure, copper cover will be made. -> reduce background which mimic signals.
  - EP to remove copper surface RI.
  - QC to prevent additional surface RI after EP.

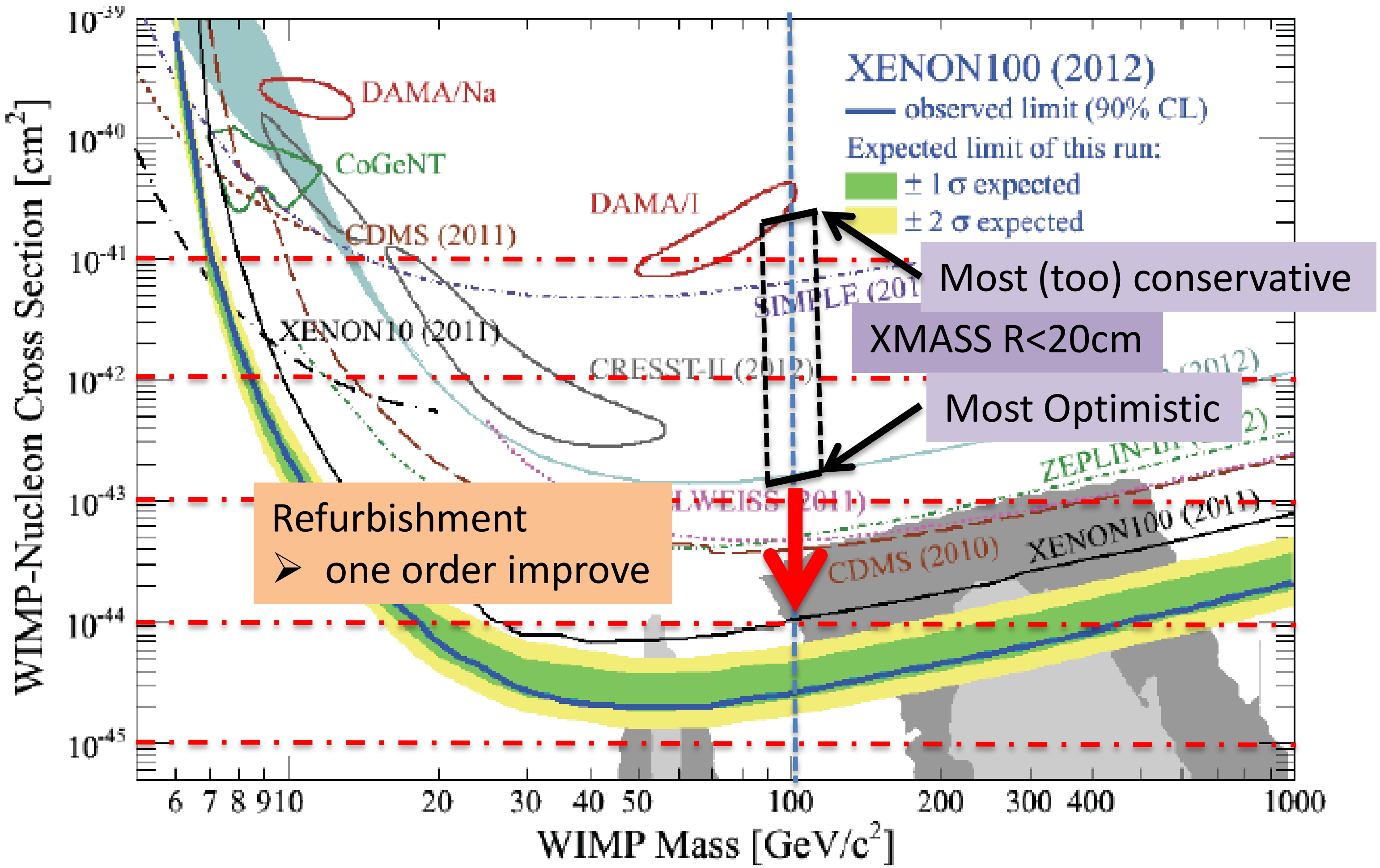






Expected sensitivity with fiducialization

Spin Independent

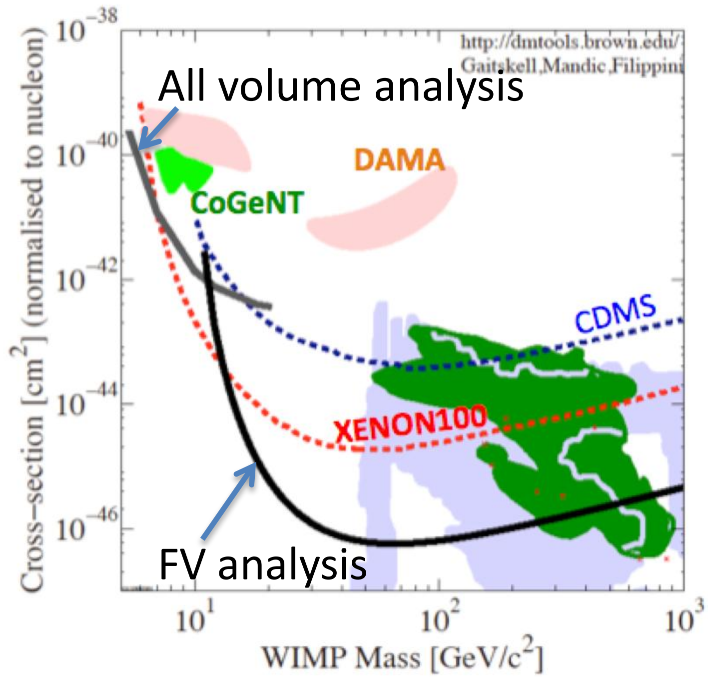


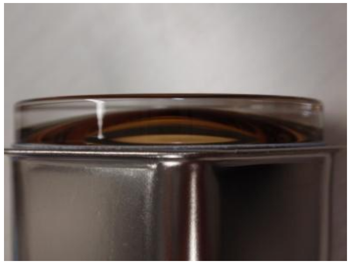
summary

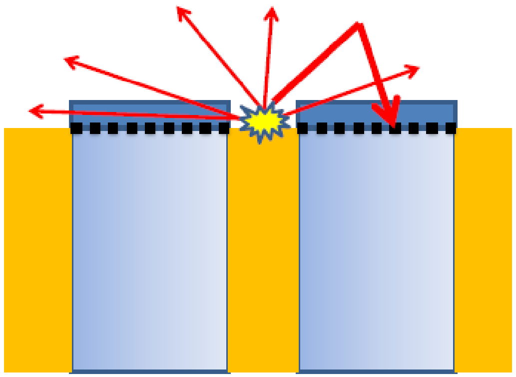
- XMASS construction and operation is done with 835kg liquid xenon.
  - Best photon yield (14.7pe/keVee)
  - Low mass WIMP search/solar axion search are carried out.
  - Detector refurbishment and software improvement is ongoing. The next run will start in summer 2013.

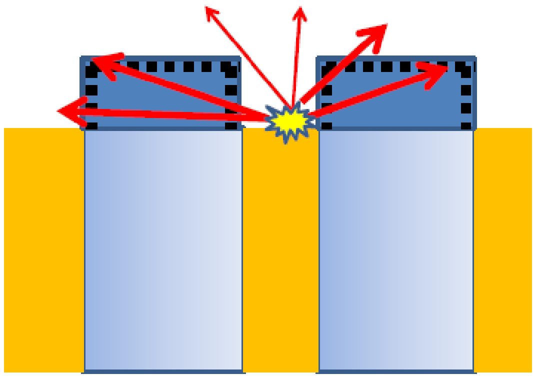
XMASS 1.5 as a next step

- Larger detectors have many advantages. 1t FV (5t total).
- We can use U-free Al in hand.
- Surface BG must be controlled.
- New PMTs being developed help to identify surface events.

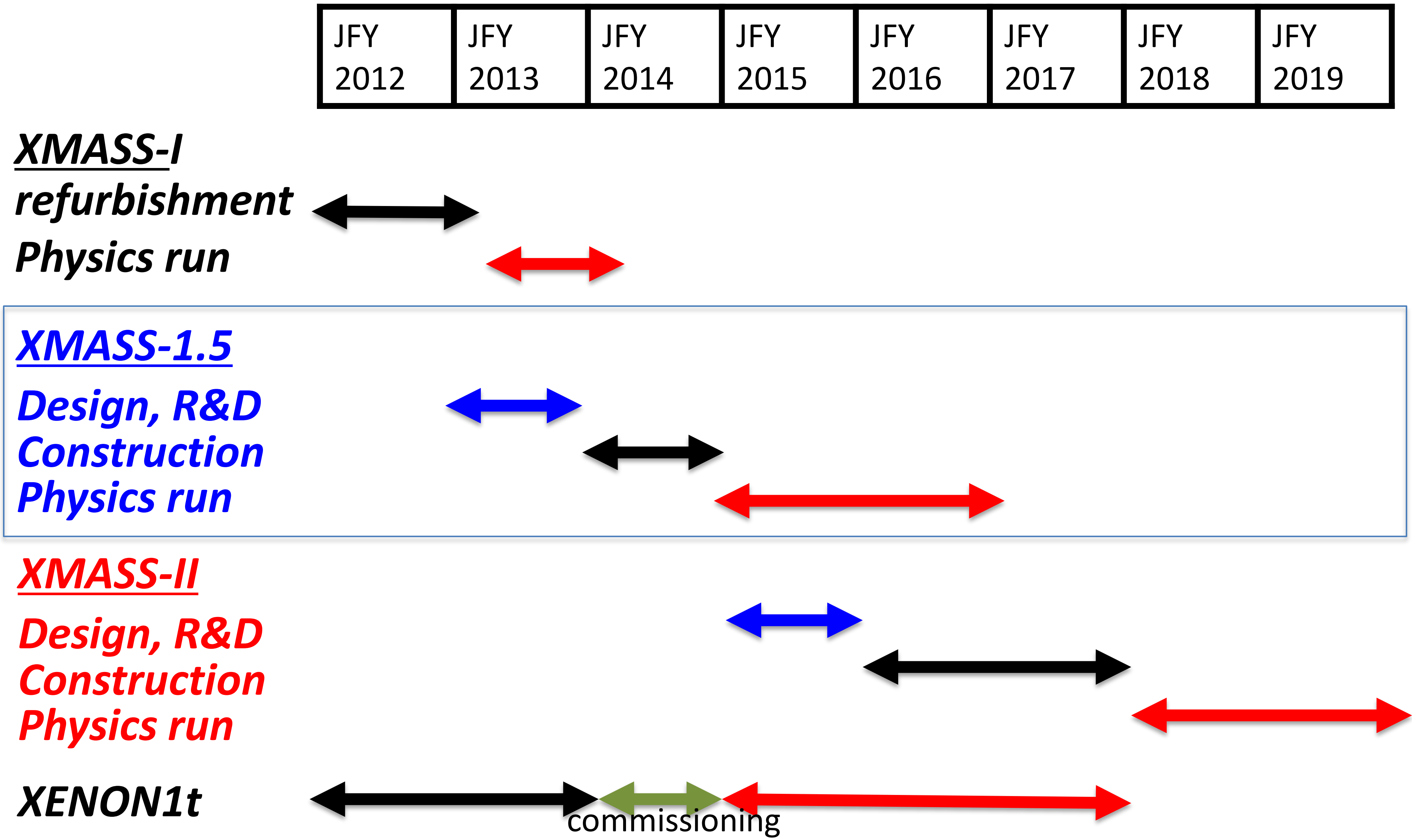








schedule


JFY 2012
JFY 2013
JFY 2014
JFY 2015
JFY 2016
JFY 2017
JFY 2018
JFY 2019
XMASS-I
refurbishment
Physics run
XMASS-1.5
Design, R&D
Construction
Physics run
XMASS-II
Design, R&D
Construction
Physics run
XENON1t
commissioning